2000

Effects of Intermittent Lighting on Breeder Chicks Provided with "In-Transit" Nutrients

Tao Han
Iowa State University

Hongwei Xin
Iowa State University, hxin@iastate.edu

Effects of Intermittent Lighting on Breeder Chicks Provided with "In-Transit" Nutrients

Abstract

In-transit supply of nutrients and water supplement is essential to maintaining good chick quality and well-being during long, international shipments. Although chicks require light to promote ingestion of nutrients, supply of continuous in-transit lighting is impractical. This study compared four intermittent lighting regimens of 1L:5D, 5L:10D,10L:10D, and 5L:15D applied to a three-day simulated transport period with regard to chick performance and energetics during the treatment period and a four-day subsequent growth period. The four lighting regimens produced similar seven-day chick performance, although chicks under 10L:10D had a somewhat higher body mass loss and metabolic rate than birds in other regimens during the three-day treatment period ($P < 0.05$). The results suggest the existence of flexibility in providing in-transit lighting for shipping chicks. Significant differences in the heat and moisture production rate of the chicks were observed between light and dark periods, with the response values being 21 to 27% lower in the dark period than in the light period. The results further suggest that chicks in transit would benefit the most from sufficient lighting to ingest necessary nutrients but then remaining in darkness to conserve body energy.

Keywords

Transportation, Breeder chicks, Photoperiod, Energetics, Mortality, Well-being

Disciplines

Agriculture | Bioresource and Agricultural Engineering

Comments

Journal Paper No J-18686 of the Iowa Agriculture and Home Economics Experiment Station, Iowa State University, Project No. 3311. Financial support for the study was provided by the U.S. Poultry and Egg Association and is acknowledged with gratitude. Mention of vendor or product names is for presentation clarity and does not imply endorsement by the authors or Iowa State University nor exclusion of other suitable products.

This article is from *Transactions of the ASAE* 43, no. 6 (2000): 1767–1770.

EFFECTS OF INTERMITTENT LIGHTING ON BREEDER CHICKS PROVIDED WITH "IN-TRANSIT" NUTRIENTS

T. Han, H. Xin

ABSTRACT. *In-transit supply of nutrients and water supplement is essential to maintaining good chick quality and well-being during long, international shipments. Although chicks require light to promote ingestion of nutrients, supply of continuous in-transit lighting is impractical. This study compared four intermittent lighting regimens of 1L:5D, 5L:10D,10L:10D, and 5L:15D applied to a three-day simulated transport period with regard to chick performance and energetics during the treatment period and a four-day subsequent growth period. The four lighting regimens produced similar seven-day chick performance, although chicks under 10L:10D had a somewhat higher body mass loss and metabolic rate than birds in other regimens during the three-day treatment period ($P < 0.05$). The results suggest the existence of flexibility in providing in-transit lighting for shipping chicks. Significant differences in the heat and moisture production rate of the chicks were observed between light and dark periods, with the response values being 21 to 27% lower in the dark period than in the light period. The results further suggest that chicks in transit would benefit the most from sufficient lighting to ingest necessary nutrients but then remaining in darkness to conserve body energy.*
Keywords. *Transportation, Breeder chicks, Photoperiod, Energetics, Mortality, Well-being.*

As the shipment of breeder chicks from the United States to international customers continues to increase, maintaining good performance (livability and body mass) and well-being of the birds at destination has become a major concern and challenge for the U.S. breeder industry. Xin and Rieger (1995) investigated the physical conditions and chick performance during air transport of day-old breeder chicks from central Iowa to Asia. The results showed a proportional relationship between journey duration and early chick mortality. Specifically, under the extreme journey duration of three days, the seven-day mortality reached 50% of the birds shipped. Tanaka and Xin (1997) investigated means to improve airflow characteristics of the shipping containers. Xin (1997) quantified the effects of potential in-transit fluctuating temperatures on performance of neonatal chicks. Xin and Lee (1996) found that a supply of both feed and water supplement improved the subsequent performance of chicks following long-journey transport. The presence of light is critical in promoting chicks to eat or drink. However, continuous supply of in-transit lighting is impractical for long-distance air transport (per communication with commercial airline companies). Xin and Lee (1996) found that use of intermittent lighting of 1L:5D produced similar chick livability as with continuous lighting. The objective of this study was to further investigate alternative intermittent lighting regimens for shipment of day-old chicks provided with in-transit nutrients.

Article was submitted for publication in November 1999; reviewed and approved for publication by the Structures & Environment Division of ASAE in August 2000.

Journal Paper No J-18686 of the Iowa Agriculture and Home Economics Experiment Station, Iowa State University, Project No. 3311. Financial support for the study was provided by the U.S. Poultry and Egg Association and is acknowledged with gratitude. Mention of vendor or product names is for presentation clarity and does not imply endorsement by the authors or Iowa State University nor exclusion of other suitable products.

The authors are **Tao Han**, Graduate Research Assistant, and **Hongwei Xin**, ***ASAE Member Engineer***, Associate Professor, Department of Agricultural & Biosystems Engineering, Iowa State University, Ames, Iowa. **Corresponding author:** Dr. H. Xin, Iowa State University, Agricultural & Biosystems Engineering, 203 Davidson Hall, Ames, IA 50011-3080, phone: 515.294.9778, fax: 515.294.9973, e-mail: <hxin@iastate.edu>.

MATERIALS AND METHODS

EXPERIMENTAL CHICKS AND ENVIRONMENT

Hy-Line (Hy-Line International, Dallas Center, Iowa) TK male breeder chicks with an initial body mass (IBM) of 38 to 41g were used in this study. The male breeder chicks had been shown by our research group (unpublished data) to respond similarly to post-hatch nutritional and environmental conditions as their female counterparts. Within five hours of hatching, the chicks housed in 16 commercial shipping containers of 80 chicks each were delivered for 50 km from the hatchery to our Livestock Environment and Animal Physiology (LEAP) Research Laboratory at Iowa State University, Ames, Iowa. Upon arrival, the chicks were weighed and provided with 200 g starter feed (20.5% protein and 3,047 kcal/kg ME) and 300 g Aqua-Jel (a water supplement, Transport Container Corporation, Columbus, Ohio) per compartment of 20 chicks. The feed and Aqua-Jel were applied on the honeycomb-surfaced bedding of the container (Note: The honeycomb-surfaced bedding is typically used by the industry in shipping chicks). The chicks in containers were then randomly assigned to four environment-controlled calorimeter chambers, where the containers were evenly distributed on an excelsior-padded chamber floor. During the experiment, the cardboard lids of the containers were replaced with poultry netting to enhance air exchange between the chicks and the surrounding environment. Air temperature near the chick level was kept at 29.4 ± 0.3°C with a relative humidity (RH) of 40 ± 5%. This RH was higher than what is normally seen during the commercial air transport (20 to 30%). Evaporation of the Aqua-Jel contributed to the higher RH.

Lighting Regimens

Four intermittent lighting regimens were tested during a 72 h posthatch period: 1L:5D (1 h light and 5 h darkness), 5L:10D, 10L:10D, and 5L:15D cycles. Programmable fluorescent lighting was used to provide a 26 lux (2.5 fc) illumination at the chick level. After the 72 h or three-day treatment, the chicks were raised with *ad libitum* feeding and continuous lighting for four days. Mortality and morbidity were monitored and recorded daily throughout the trial period. Body mass (BM) was measured at the beginning of the trial, at the end of the three-day treatment, and again at the end of the seven-day trial period.

Measurement of the Chick Energetic Responses

Total heat production rate (THP, W/kg) was measured using the indirect calorimetry technique (Xin and Harmon, 1996). Moisture production rate (MP, g/kg·h) was inclusive of all water sources of the environment. Sensible heat production rate (SHP, W/kg) was the difference between THP and the MP-based latent heat production rate. A detailed description of the LEAP calorimeter system and calculation equations had been presented elsewhere (Xin and Harmon, 1996). All the energetic responses were measured at 30-min intervals and converted to unit BM basis. Daily BM of the chicks was estimated by linear interpolation of two adjacent BM measurements.

Each lighting regimen was replicated four times, following a completely randomized block design. Thus, there were 1,280 chicks per regimen or 5,120 chicks for the entire experiment. Analysis of variance (ANOVA) and Duncan's multiple mean comparison were conducted using SAS programs to evaluate the treatment effects. Han (1997) gave a more detailed description of the experimental facilities and procedures.

Results and Discussion

Chick BM Change

The average BM changes of the chicks during the three-day treatment period and seven-day trial period are summarized in table 1. The BM in all treatments decreased during the treatment period, with chicks in the 10L:10D regimen having higher BM loss (9.6% IBM) than chicks in the other regimens (7.5% IBM) ($P < 0.05$). The higher BM loss for the 10L:10D regimen was presumably attributed to the higher metabolic rate (see section on energetic responses) that was caused by the longer light hours and thus higher activity levels. The BM loss for all the treatments was presumably due to limited feed intake that was below the maintenance requirement of the chicks. Still, these BM loss values were much lower than the 18 to 20% losses that would have occurred if the feed and Aqua-Jel had not been provided (Xin and Lee, 1996). Chicks in all regimens had a similar BM at the end of the four-day subsequent growth period.

Table 1. Body mass changes of newly hatched chicks subjected to four lighting regimens*

Lighting Regimen		Initial BM (g/chick)	3-d BM (g/chick)	3-d Change (% IBM)	7-d BM (g/chick)	7-d Change (% IBM)
1L:5D	$\bar{x}$	39.6	36.6^a	$–7.5^b$	67.9	71.4
	SE	0.7	0.5	0.8	2.8	4.2
5L:10D	$\bar{x}$	39.4	36.5^a	$–7.5^b$	68.5	73.6
	SE	0.7	0.4	0.8	2.7	4.0
10L:10D	$\bar{x}$	39.6	35.8^b	$–9.6^a$	67.7	70.9
	SE	0.7	0.6	0.4	2.6	3.6
5L:15D	$\bar{x}$	39.4	36.5^a	$–7.4^b$	67.8	71.7
	SE	0.7	0.4	0.8	2.4	3.1

* Column means with different superscript letters are significantly different ($P < 0.05$).

Chick Mortality

Cumulative mortality rate (% chicks placed) for the 1L:5D, 5L:10D, 10L:10D, and 5L:15D regimens (mean ± SE) were, respectively, 0.70 ± 0.07, 1.09 ± 0.30, 0.55 ± 0.20, 1.02 ± 0.30 at three days of age, and 1.25 ± 0.40, 1.41 ± 0.30, 1.09 ± 0.20, 1.17 ± 0.30 at seven days of age. No significant difference was detected ($P > 0.05$) among the regimens for the three-day or the seven-day period, although chicks under 10L:10D had the lowest numerical value during both the three-day treatment and the seven-day trial period. The mortality rates of the present study paralleled those of the previous study (1.27%) under continuous lighting (Xin and Lee, 1996). The results indicate that any one of the intermittent lighting regimens tested in this study may be used as an in-transit lighting program.

Energetic Responses

The time-weighted average (TWA) heat and moisture production rates of the chicks during the three-day lighting treatments are listed in table 2. The corresponding respiratory quotient (RQ), O_2 consumption, and CO_2 production rates are listed in table 3. The average responses were further divided into light and dark periods. Chicks under all the regimens had similar average energetic responses with the exception of those subjected to 10L:10D that had a higher THP of 11.1 W/kg ($P < 0.05$). The higher TWA THP under 10L:10D was attributed to its longest (both absolute and relative) light period, although the average THP for both the light and dark periods was the

Table 2. Heat and moisture production of newly hatched chicks provided with feed and water replacement and intermittent lighting for three days (air temperature = 29.4 ± 0.3°C, RH = 40 ± 5%)

Lighting Regimen		THP (W/kg)			MP (g H_2O/h-kg)			SHP (W/kg)		
		Light	Dark	TWA	Light	Dark	TWA	Light	Dark	TWA
1L:5D	$\bar{x}$	13.6_1	9.7_2	10.3^b	9.8_1	7.5_2	7.9	6.9_1	4.6_2	5.0
	SE	1.1	0.4	0.4	0.6	0.3	0.2	0.7	0.3	0.3
5L:10D	$\bar{x}$	12.8_1	9.7_2	10.8^b	9.5_1	7.5_2	8.2	6.3_1	4.7_2	5.3
	SE	0.4	0.6	0.4	0.3	0.2	0.0	0.3	0.5	0.4
10L:10D	$\bar{x}$	12.6_1	9.2_2	11.1^a	9.2_1	6.9_2	8.2	6.3_1	4.6_2	5.6
	SE	0.3	0.3	0.2	0.1	0.3	0.1	0.4	0.2	0.3
5L:15D	$\bar{x}$	13.4_1	9.9_2	10.1^b	10.1_1	7.5_2	8.1	6.6_1	4.8_2	5.1
	SE	0.7	0.6	0.4	0.2	0.3	0.1	0.5	0.5	0.4

Note: Column means with different superscript letters are significantly different ($P < 0.05$). Row means with different subscript numbers within each response variable are significantly different ($P < 0.05$). TWA = time-weighted average.

Table 3. Respiratory quotient (RQ), O_2 consumption, and CO_2 production of limited-fed, newly hatched chicks during 72-h intermittent lighting treatments (air temperature = 29.4 ± 0.3°C, RH = 40 ± 5%)

Lighting Regimen		RQ			O_2 (mL/s(kg)			CO_2 (mL/s(kg)		
		Light	Dark	TWA	Light	Dark	TWA	Light	Dark	TWA
1L:5D	$\overline{x}$	0.84	0.83	0.83	0.66_1	0.48_2	0.51	0.56_1	0.39_2	0.42^b
	SE	0.02	0.01	0.01	0.05	0.02	0.02	0.04	0.02	0.02
5L:10D	$\overline{x}$	0.83	0.82	0.83	0.63_1	0.48_2	0.53	0.52_1	0.39_2	0.44^b
	SE	0.02	0.02	0.02	0.02	0.03	0.02	0.01	0.02	0.01
10L:10D	$\overline{x}$	0.83	0.85	0.84	0.62_1	0.45_2	0.54	0.51_1	0.38_2	0.46^a
	SE	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01
5L: 15D	$\overline{x}$	0.84	0.83	0.83	0.66_1	0.49_2	0.52	0.55_1	0.40_2	0.43^b
	SE	0.02	0.02	0.02	0.04	0.03	0.02	0.02	0.03	0.01

NOTE: Column means with different superscript letters are significantly different ($P < 0.05$). Row means with different subscript numbers within each response variable are significantly different ($P < 0.05$). TWA = time-weighted average.

lowest among the treatments. The higher THP coincided with a higher BM loss as noted previously. Except for RQ, the energetic responses for the light period were significantly higher than those for the dark period. Figure 1 provides an example of the dynamic profile of the energetic responses to light and darkness for chicks under 5L:10D. It can be derived from table 2 that the responses during the dark period were generally 73 to 79% of those during the light period. This outcome coincided with the 25% reduction in heat and moisture production rate of broiler chickens during darkness as measured by Xin et al. (1996). Thus, keeping chicks in darkness would be an effective way to help them conserve body energy. The THP values under all the treatments were lower than the maintenance level of 16 W/kg as determined by $7 \cdot M^{0.75}$ (W/animal), where M is BM in kg (CIGR, 1992). The loss of BM was consistent with this outcome. The THP values of this study, however, were much greater than those of chicks undergoing fasting during post-hatch period (7.4-8.8 W/kg) as reported by previous studies (Mission, 1975; Van der Hel et al., 1990; Xin and Harmon, 1996). RQ values of this study (0.82-0.85) were also much higher than those of fasting chicks (0.74) (Xin and Harmon, 1996). The availability of nutrients is believed to be responsible for the differences.

The average heat and moisture production rates and RQ during the four-day subsequent growth period under continuous lighting are presented in table 4. Regardless of the previous (three-day) lighting regimens, the energetic responses were almost identical among all the chicks during the growth period. The THP of 19.1 W/kg of this study was

Table 4. Average energetic responses of chicks during a 4-d, *ad-lib* fed growth period subsequent to the 72-h lighting treatments (air temperature = 29.4 ± 0.3°C, RH = 40 ± 5%)

Lighting Regimen		THP (W/kg)	MP (g $H_2$0/h·kg)	SHP (W/kg)	RQ (V_{CO_2}/V_{O_2})
1L:5D	$\overline{x}$	19.1	16.4	8.0	0.93
	SE	0.5	0.5	0.4	0.01
5L:10D	$\overline{x}$	19.1	16.2	8.1	0.92
	SE	0.3	0.5	0.2	0.01
10L:10D	$\overline{x}$	19.2	16.2	8.2	0.92
	SE	0.6	0.3	0.6	0.00
5L: 15D	$\overline{x}$	19.0	16.2	7.9	0.93
	SE	0.4	0.2	0.4	0.02

* There were no significant differences among the regimens in any of the response variables.

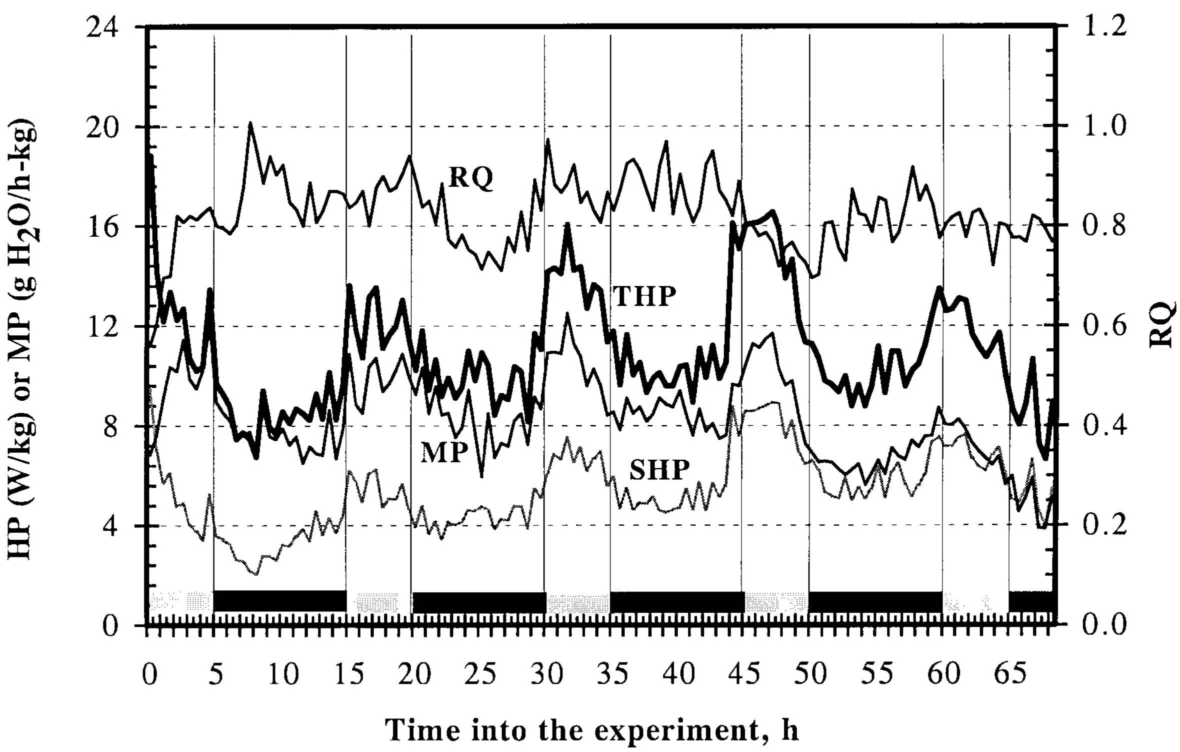

Figure 1–Dynamic energetic responses of neonatal chicks to light and dark period under the 72-h 5L:10D lighting regimen (lighter shade denotes light period and darker shade denotes dark period). (THP = total heat production rate; SHP = sensible heat production rate; MP = moisture production rate; RQ = respiratory quotient).

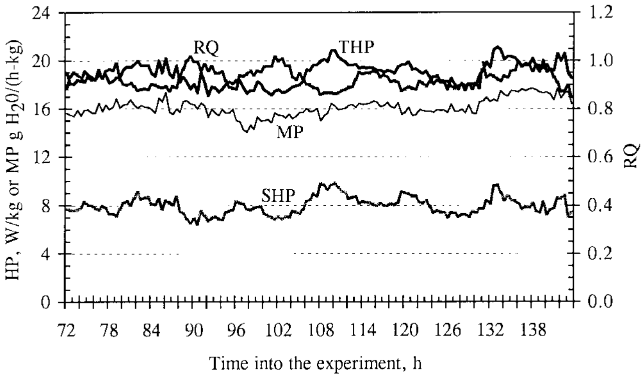

Figure 2–Dynamic energetic responses of chicks during three-day growth period under continuous lighting and *ad-lib* feeding after the 72-h intermittent lighting regimens (average of four treatments) (THP = total heat production rate; SHP = sensible heat production rate; MP = moisture production rate; RQ = respiratory quotient).

Table 5. Correlation coefficient (γ) between RQ and SHP, THP, and MP

		SHP	THP	MP
RQ	γ	–0.636	–0.413	0.136
	P	0.0001	0.0001	0.1048

6.7% higher than that of 17.9 W/kg for broiler chickens at the same age and 29.4°C (Reece and Lott, 1982). The slightly higher THP of the current study could have arisen from the lighter BM of the layer breeder chicks, thus a greater surface-to-volume ratio. However, the SHP and MP of this study, 8.1 W/kg and 16.2 g H_2O/(h·kg), were respectively higher and lower than SHP and MP from Reece and Lott (1982) for broiler chicks, 4.0 W/kg and 20.4 g H_2O/(h·kg), respectively. The differences were presumably attributed to different drinking systems involved, i.e., nipple drinker in the present study vs. open trough drinker of the cited study, which would have led to different moisture conditions of the litter.

Figure 2 shows the average dynamic THP, MP, SHP, and RQ responses of the four regimens during the post-treatment period. Note that although the chicks were raised under continuous lighting, their energetic responses showed circadian rhythms. Interestingly, the dynamic pattern of RQ was quite opposite of that for THP or SHP. The negative relationships are further quantified by correlation analysis between RQ and the other energetic variables, as shown in table 5. Negative correlation between RQ and HP had been reported in fasted turkeys subjected to heat stress conditions (Xin et al., 1992). In this case, however, the chicks were under thermoneutrality and *ad-libitum* feeding. This negative correlation was speculated to result from bird activities (e.g., feeding, drinking, and locomotion) which augmented THP by a temporarily higher proportion of O_2 consumption than the CO_2 production. The overall RQ values (0.91 to 0.93) were quite normal for birds fed *ad-libitum*.

Conclusions

Four intermittent lighting regimens of 1L:5D, 5L:10D, 10L:10D, and 5L:15D during a three-day simulated transport period were compared with regard to chick performance and energetics during the treatment and a four-day subsequent growth period. The results indicated the following:

1. The four lighting regimens, in conjunction with the supply of feed and Aqua-Jel water replacement, all produced similar seven-day body mass change, satisfactory seven-day mortality rate (1.1 to 1.4%), and similar energetic responses during the four-day subsequent growth period.
2. Light or darkness has a major impact on chick energetics, with darkness reducing heat and moisture production by 22 to 27%. Hence, keeping chicks in intermittent darkness will help them conserve body energy.
3. Chicks subjected to the nutrient supply and intermittent lighting had a metabolic rate lower than their maintenance level but higher than the fasting level.

References

CIGR. 1992. Second Report of Working Group on Climatization of Animal Houses, 18-19. Ghent, Belgium: Center for Climatization of Animal Houses—Advisory Services, Faculty of Agricultural Sciences, State University of Ghent.

Han, T. 1997. Performance and energetics of neonatal chicks as influenced by intermittent “in-transit” lighting regimens. M.S. thesis. Ames, Iowa: Iowa State University.

Mission, B. H. 1975. The effects of temperature and relative humidity on thermoregulatory responses of grouped and isolated neonatal chicks. *J. Agric. Sci. Camb.* 86: 35-43.

Reece, F. N., and B. D. Lott. 1982. Heat and moisture production of broiler chickens during brooding. *Poul. Sci*. 61: 661-666.

Tanaka, A., and H. Xin. 1997. Effects of structural and stacking configuration of containers for transporting chicks on their microenvironment. *Transactions of the ASAE* 40(3): 777-782.

Van der Hel, W., M. W. A. Verstegen, A. M. Henken, and H. A. Brandsma. 1990. The upper critical ambient temperature in neonatal chicks. *Poultry Sci.* 70: 1882-1887.

Xin, H. 1997. Mortality and body weight of neonatal breeder chicks as influenced by air temperature fluctuations. *Appl. Poultry Res.* 6: 199-204.

Xin, H., J. A. DeShazer, and M. M. Beck. 1992. Responses of pre-fasted growing turkeys to acute heat exposure. *Transactions of the ASAE* 35(1): 315-318.

Xin, H., and J. D. Harmon. 1996. Responses of neonatal chicks to posthatch holding environment. *Transactions of the ASAE* 39(6): 2249-2254.

Xin, H., and K. Lee.1996. Use of Aqua-Jel and feed for nutrient supply during long journey air transport of baby chicks. *Transactions of the ASAE* 39(3): 1123-1126.

Xin, H., and S. R. Rieger.1995. Physical conditions and mortalities associated with international air transport of young chicks. *Transactions of the ASAE* 38(6): 1863-1867.

Xin, H., J. L. Sell, and D. U. Ahn. 1996. Effect of light and darkness on heat and moisture production of broilers. *Transactions of the ASAE* 39(6): 2255-2258.